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INFLUENCE OF STRUTS AND STAYS ON THE SPEED OF AN AIRPLANE.

By

Engineer V. Heidelberg.

Translated from
"Zeitschrift für Flugtechnik und Motorluftschiffahrt,"
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This work was done in the airplane experiment division of the air service on the Rechlin airdrome on Muritz Lake in the fall of 1918. The airplane speeds were measured with photographic registering theodolites of the firm of Karl Bamberg, Berlin-Friedenau.

The airplane used was the Fokker D VII with two fixed machine guns, just as it was used on the battle front.

The load carried consisted of full fuel and oil tanks, but no munitions nor supplementary load. Weight without struts and stays was 900 kg.

The airplane was tested:

1. For horizontal speed at 600 m. altitude;
2. For climbing ability.

For this purpose flights were made:

1. After the removal of the wing struts without reinforcing the wings, which would have been structurally necessary. The lower wings could consequently rotate somewhat about their wing spars. The airplane flew smoother than before and was considerably less sensitive to lateral motions of the rudder. Observations indicated that the trailing edge of the lower wing was bent upward. This reduced the attacking angle of the lower wing and caused a stronger loading of the upper wing. The changed shrinking rela-

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tion of the upper and lower wings during flight was not measured.

2. With the struts as employed at the battle front. Weight of struts was 2 x 2.85 = 5.7 kg.

3. With added stay wires, not formerly employed. The wire cords were loosely attached to the wings after the manner of the single-strut D airplanes, so that each front and rear stay together formed a plane of support passing through the point of attachment to the wing. Steel cords of 4.8 mm. were employed. Their total length was 20.3 m. and their weight was 2.5 kg. In flight the stays were taut. No change in the aerodynamic relations of the airplane was considered.

The weight increase of 5.7 and 5.7 + 2.5 kg. was offset by removing a like weight of fuel. The air temperatures and pressures were measured for determining the air density at 1, 2, 3, 4, 4.5 and 5 km. altitude.

The horizontal speed at 600 m. altitude was measured by two successive quadrangular flights, the engine speed being about 1440 r.p.m. Errors of observation were corrected as much as possible and the proportional error determined in each instance. Since comparative measurements were undertaken, the flights had to be made under like conditions. The flights for determining the horizontal speed were made under like conditions of altitude, air density and revolution speed. These conditions could be readily fulfilled by the writer, who piloted the airplane, since the flights were made on a still afternoon, when there was no change

in the atmospheric conditions during the short period of time occupied by the tests. For the horizontal speed measurement, the low altitude of 600 m. was chosen, in order to have approximately the same engine efficiency as on the ground.

Let index

1 be the experiment series without struts;

2 " " " " with "

3 " " " " " stay wires.

The measurements gave for the horizontal speeds:

v_1 = (49.40 ± 0.340) m/s = 177.6 km/h.

v_2 = (49.52 ± 0.535) m/s = 178 km/h.

v_3 = (47.72 ± 0.655) m/s = 172 km/h.

As the result of the measurements for the estimation of the influence of struts and stays on the horizontal speed, we may consider the following points:

On account of too weak internal construction of the lower wing, the influence of the struts on the speed was not evident. In fact, the airplane had a smaller horizontal speed without struts than with struts, probably on account of the circumstance that the lower wing yielded without struts. A comparison of v_2 and v_3 was however possible, since the wings with struts were mutually braced. Their looseness did not change the aerodynamic relations. The loss in horizontal speed was comparatively small (from 178 to 172 km/h.). It was to be expected that the difference in speed at great heights would be still less, since the

share of the total resistance offered by the stays was still less there.

On the basis of these results, it was attempted to calculate the resistance of the stays, but it was evident that the technical data, lying at the basis of this fine calculation, did not suffice for the accurate determination of these values.

It seems doubtful as to whether it is advisable to forego the advantage of external stays for the sake of obtaining such a slight increase in speed. With the employment of such bracing, it is possible to construct a supporting structure with so much reserve strength, as to insure a sufficient remaining strength, after the injury or loss of some supporting part.

In comparing the influence of struts and stays on the climbing speed of an airplane, it does not matter whether we employ the barograph climbing curves or the climbing speeds obtained by numerical differentiation. The latter were employed, since inaccuracies occurred in constructing tangents to the barograph curves by the graphic method. If we indicate the altitude by z, the climbing speed by w, the pressure in kg/sq.m. by p and the air density by γ (kg/cu.m.), we have:

$$w_z = \frac{dz}{dt} = \frac{dz}{dp} \times \frac{dp}{dt} = -\frac{1}{\gamma} \times \frac{dp}{dt}$$

The temporary pressure change $\frac{dp}{dt}$ is obtained by drawing the air pressure curves (barograph curves) in rectangular coordinates, from which the air pressure is read for like periods of time Δt (for example, every two minutes).

In most instances this determination of Δp has proved sufficient. Only for very swift climbing airplanes a larger number of readings must be taken.

The pressure difference in mm. of Hg. of a period $\Delta t = 120$ seconds multiplied by the specific weight of mercury (13.6) gives the value of Δp with sufficient accuracy.

Every thousand meters during the flight, the temperature was read on two spirit thermometers which agreed well. The climbing speed was then simplified to

$$w_z = \frac{\Delta p \times 13.6}{120 \times \gamma} = 0.1133 \frac{\Delta p}{\gamma} \text{ m/s}$$

The results were then reduced with reference to the air density and then to the yearly average for enabling comparison. They are given in the following table and also graphically in Figs. 1 to 3.

<u>Average Values for Every Three Flights</u>.

Altitudes in km.		0-1	1-2	2-3	3-4	4-5	0-5
		Climbing times in minutes.					
Without struts	actual	2.75	3.75	5.0	7.0	12.0	30.5
	reduced	2.5	3.5	5.0	6.75	13.25	31.0
With struts	actual	3.0	3.5	4.5	6.5	11.5	29.0
	reduced	2.75	3.25	4.25	6.25	9.5	26.0
With struts and staywires	actual	3.0	4.5	6.0	8.0	12.5	34.0
	reduced	2.5	4.0	6.25	8.75	13.5	35.0

The resulting curves are quite irregular, while it was to be expected that they would be flat and would be approximately straight lines. The irregular course of the curves may be variously explained. At some points perhaps the airplane did not fly at its full speed. We would then be justified in constructing a tangent to the highest value and thus obtaining a theoretical curve of the climbing speed. Irregularities of the curve may also be due to local variations in the air density, which were not shown by the temperature and pressure readings. Lastly, there is also an inaccuracy in the process of calculation, since the air density and pressure curves are constructed in 1000 meter sections, that is, in periods of 3 to 10 minutes, while the speed curves are constructed in two-minute sections. This inaccuracy of the calculating process prohibits offsetting by means of a tangent to the highest value, but facilitates its construction by means of a line lying between the tangent and the mean values. This compensation was made in the present article. By a comparison of the three climbing experiments, it may be determined whether the best flight or the mean of two or three flights should be taken as the unit of comparison. Since the starting point for the comparison is not decisive, but only indicates a parallel displacement, both methods are combined in Figs. 4 and 5. The character of both figures is identical.

The chief result for the estimation, as to how much the climbing ability is influenced by struts and stays, is that on the Fokker D VII the best times were made with struts. On the contrary,

the climbing ability was considerably impaired by the addition of stay wires.

The fact that in spite of the increased resistance of the airplane with struts but without stays, the climbing times are better than for the airplane without struts, demonstrates more clearly than in the horizontal speed measurements, that the lower wings of an airplane are too yielding without struts. If the lower wings were braced internally, so that such a distortion were impossible, then curve I would doubtless lie above curve II.

The endeavors of airplane factories to build wings without stay wires is fully justified by the fact that stayless airplanes show decidedly better climbing times than those with strong stay wires.

Summary.

From the measurements obtained with a Fokker D VII, which was flown both with struts and after their removal, as also with both struts and stays, it follows that only a slight increase in horizontal speed was shown by stayless airplanes over those with external stay wires, but that, on the other hand, the former had a considerably greater climbing speed.

Translated by the National Advisory Committee for Aeronautics.

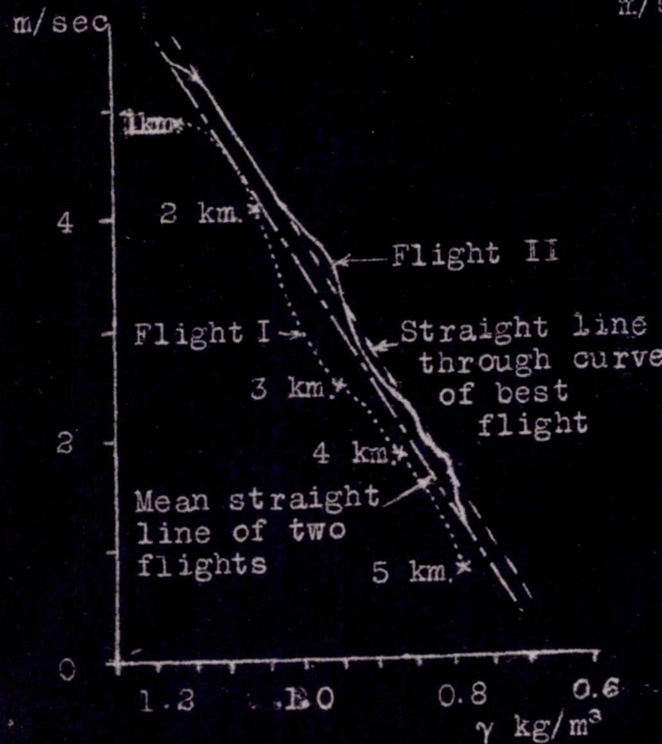

Fig. 1.

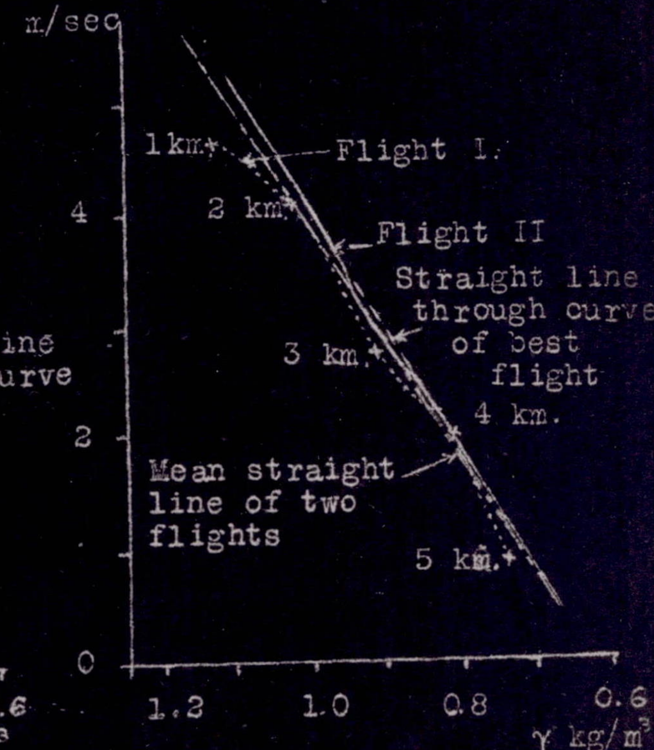

Fig. 2.

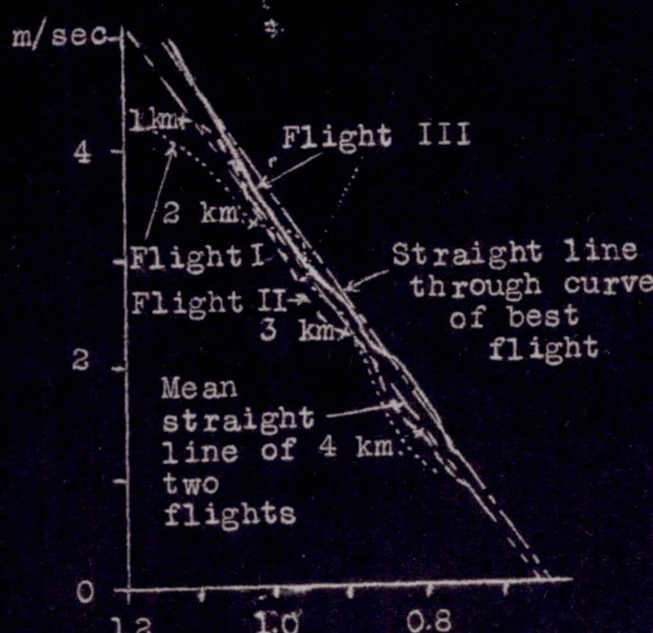

Fig. 3

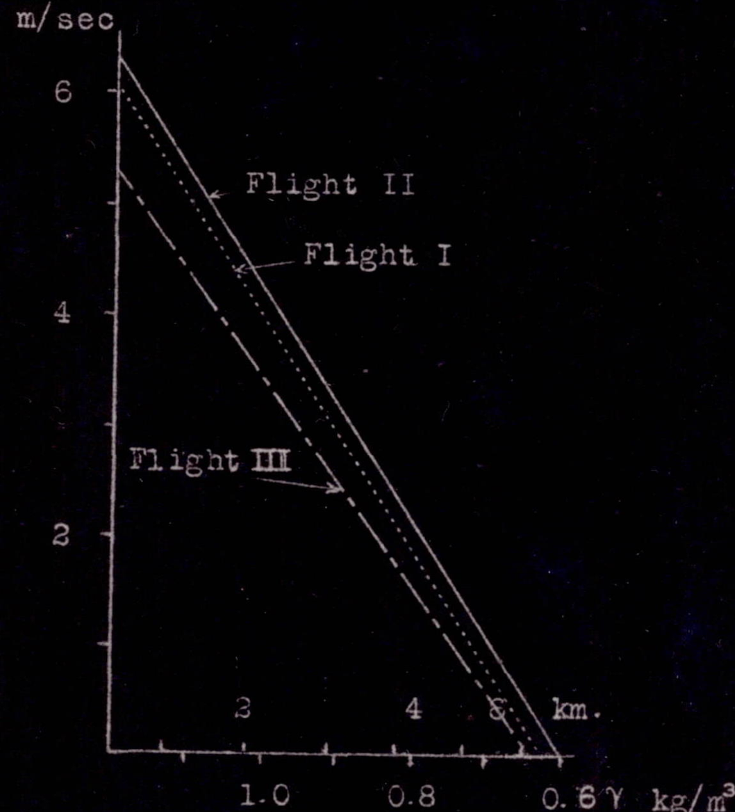
m/sec
6
4
2
Flight II
Flight I
Flight III
2
4
6
km.
1.0
0.8
0.6 γ kg/m³

Fig. 4

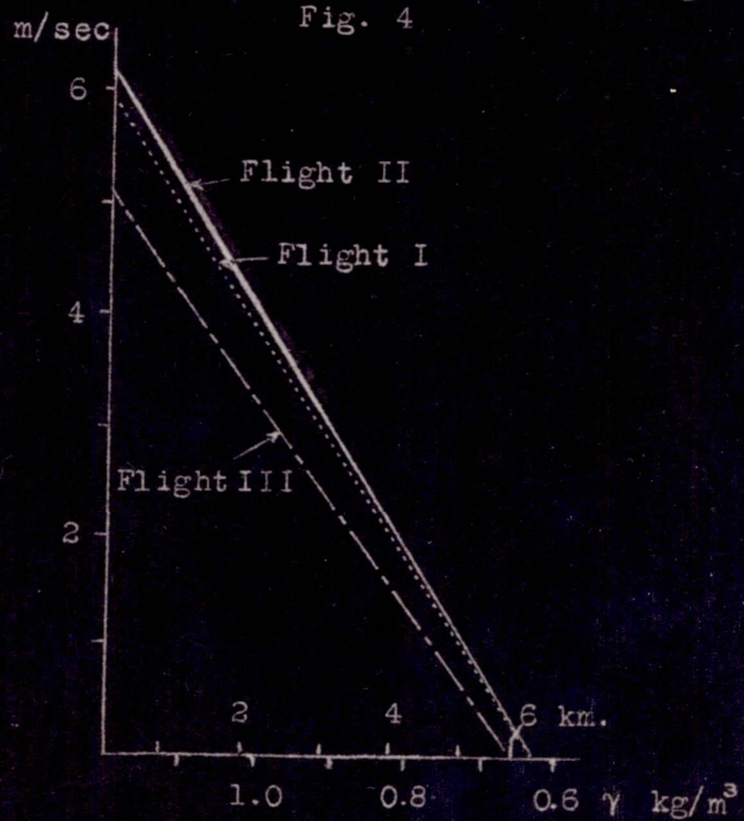
m/sec
6
4
2
Flight II
Flight I
Flight III
2
4
6
km.
1.0
0.8
0.6 γ kg/m³

Fig. 5